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FINAL REPORT

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A PROGRAM OF SUPPORT FOR HIPAS CAMPAIGNS DURING 1987

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ABSTRACT

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This is a review of the work performed during the 1987 HIPAS campaigns through 30 September 1987. During 1987, two campaigns were undertaken, one in June and one in October, to establish the level of VLF modulation which could be accomplished using the HIPAS radar facility to heat the polar ionosphere. During the June campaign, Dr. Ferraro of Penn State University established that there was sufficient current flowing in the ionosphere to enable the heater to produce detectable modulation at almost every interval. Further, using measurements of the polarization of the VLF return Dr. Ferraro was able to infer the direction of the current being modulated. We also were fortunate enough to take data during the passage of a westward-travelling surge associated with a substorm onset in the College area. The analysis of this event is included in this report.

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I. Introduction

This is a report on the work performed during the 1987 HIPAS campaigns we participated in during June and October of that year. As part of the support we provided, data from the Alaska meridian chain of magnetometers and from the University of Alaska induction magnetometer were analyzed for information of the state of ionospheric currents and levels of activity present during the HIPAS operating times.

The Alaska meridian chain of magnetometers is comprised of a series of magnetometer observation stations located at approximately the same geomagnetic longitude, with the entire set spanning the auroral oval and extending into the polar cap. The chain data can be used to infer the presence of currents flowing in the ionosphere over the chain. While the state of the local ionosphere is of primary interest to HIPAS investigators, analysis of the entire chain data allows the identification of electrojets, their location, width and strength. (Details of the techniques have been outlined in previous project reports and are based upon the work of Hughes and Rostoker [1977,1979], Hughes et al. [1979] and Akasofu et al. [1983]) Using these data we can track the motions and the changes in electrojet intensities with time and make some estimates of the magnetospheric regime governing the state of the overhead ionosphere. This analysis places the state of the local ionosphere in a broader context. Some examples of the analysis of actual intervals of interest during the 1987 HIPAS campaigns is given in section II of this report.

II. Real-time data acquisition during HIPAS campaigns

A. The Alaska magnetometer chain and real-time data access through SELDADS

The Geophysical Institute of the University of Alaska operates a meridian chain of magnetometers and riometers which spans the auroral oval and extends into the polar cap. The site locations are given in Tables 1 and 2 and their locations are shown in Figure 1. The output of the flux-gate magnetometers contains the three vector components of the earth's magnetic field in a coordinate system in which H is positive northward, D is positive eastward and Z is positive downward. The magnetometer outputs are sampled at one minute intervals with a nominal digital resolution of 1 nT over a range of 4000 nT. Data from each station in the magnetometer chain is telemetered via the GOES satellite to the NOAA/ERL Space Environment Laboratory (SEL) in Boulder, CO. where it is recorded and made available in near real-time. Several of the stations have 30 MHz riometers in operation and the riometer data is also sampled at one minute intervals and returned to SEL via the GOES path.

SEL operates a data acquisition and display system (SELDADS) which is a computer based catalog of the data from a number of observatories across the continent. (The SELDADS User Manual describes the data base and is available from the SEL in Boulder, CO.) The data may be accessed from a remote site using a telephone modem to log into the SELDADS computer. Once on line, the computer provides a sequence of programs which allow the remote user to list, or plot the data from a given time. Since it takes a small amount of time to pre-process the data for the data base there is a short time delay before current data is included in the data base. This delay usually amounts to approximately 15 to 30 minutes. Thus, during HIPAS campaigns we are able to locate and analyze the nature of the polar electrojets with less than a 30 minute delay. Except during substorms and extremely active periods this ensures a reliable estimate of the location and strengths of the background currents in the ionosphere.

During 1987, data downloaded from the SELDADS data base were kept in public files on the Geophysical Institute VAX along with plotting and diagnostic routines which allow any project personnel to explore the data.

Table 1
Alaska RGON Magnetometer Chain Locations

Station	Mnemonic	Geographic Latitude	Geographic Longitude
Talkeetna	TLK	62.30	209.90
Fort Yukon	FYU	66.57	214.75
Arctic Village	AVI	68.10	214.40
Inuvik	INU	68.35	226.20
Cape Parry	CPY	70.17	235.28
Barrow	BRW	71.33	203.22
Sachs Harbor	SAH	72.00	235.00

Table 2
East-West RGON Magnetometer Chain Locations

Station	Mnemonic	Geographic Latitude	Geographic Longitude
Anchorage	ANC	61.20	210.10
College	COL	64.86	212.15
Norman Wells	NOR	65.00	233.00
Fort Simpson	FSP	61.80	238.80
Fort Smith	FSM	58.00	246.00
Lynn Lake	LYN	56.90	258.90
Narssarssuaq	NAR	61.20	314.60

B. Geophysical Institute induction magnetometer

In addition to the data from the meridian chain of magnetometers, data from and induction magnetometer, riometer and digital ionosonde are available in real-time at the Geophysical Institute. The induction magnetometer is sensitive to magnetic fluctuations between dc and 10 Hz and has a maximum sensitivity at 2 Hz. At 2 Hz the noise threshold is equivalent to a signal of approximately 0.7 milligamma or 0.7 picoTesla. With signal processing the threshold for signal detection can be reduced. The induction magnetometer can be used to provide a complete diagnostic of the ULF variations in the earth's magnetic field, complimenting the low frequency response of the flux-gate magnetometer. Signals from the induction magnetometer are available in real-time at the Geophysical Institute and are recorded digitally at 10 second intervals. During times of interest to HIPAS experimenters, the ULF data from the induction magnetometers were recorded with a 10 Hz Nyquist frequency preserving the entire bandwidth of the system. Hardware and software were developed during the 1987 campaigns for this task.

III. Examples of diagnostics from the 1987 HIPAS campaign

A. June 12, 1987

The HIPAS facilities were operated during the hours from midnight to 6am on June 12, 1987 (corresponding to 0800-1400 Universal Time) as part of a VLF experiment conducted by Dr. T. Ferraro. The HIPAS beam was modulated at 2500 Hz and Dr. Ferraro recorded VLF signals throughout the interval. As a regular part of the support we provided, the Alaska magnetometer chain data for the entire campaign interval, including June 12, were downloaded from SELDADS. Programs were written and made available on the Geophysical Institute VAX computer along with the data. The programs will plot the data in day plot form or as a latitude profile. Figures 2 through 7 show the magnetometer data from the Alaska meridian chain as well as the east-west magnetometer chain for all three magnetometer components for the entire day of June 12. A cursory reading of these data plots shows considerable activity during the the nighttime sector when several substorms were seen. (Local solar midnight at College during June of 1987 occurred at approximately 1000 UT.)

Dr. Ferraro recorded the characteristics of the 2500 Hz signal radiated by the currents modified by the HIPAS beam during the period. In a preliminary analysis, he produced a time series of the amplitude of the VLF signal for the 6 hours of operation and noticed considerable variation. When compared with the College magnetogram there he noted an obvious correlation with some of the main features of the magnetic record. For convenience, we have plotted the VLF amplitude as provided by Dr. Ferraro on the same scale as the College magnetogram data in Figure 8. First, it is obvious that by coincidence, the operation was begun just prior to a substorm onset in the College sector. The first two hours of VLF data show two peaks in signal amplitude and can be seen to correspond to the sharp peaks in the D and Z components. The sharp D and Z component spikes accompanied by a sudden decrease in the H component signals the presence overhead of the so called "westward-travelling surge" or WTS. The WTS is the harbinger of the magnetospheric substorm. After the passage to the WTS, the primary substorm electrojet appeared over the College area, centered on College.

The westward-travelling surge, occuring at the leading edge of the westward electrojet, is characterized by a strong, upward field-aligned current as well as solenoidal hall and pedersen currents in the auroral ionosphere. The strong VLF returns indicate that the HIPAS beam was modifying the currents flowing in the vicinity of the WTS. Because the HIPAS heating probably does not extend much above 120 km, it was probably the ionospheric current which suffered modulation at this time. However, because of the intense field-aligned currents present it is interesting to consider that some of the field-aligned current may have participated in the process. This is an exciting result and one which we are proposing to study further as described in section IV of this proposal.

As the westward substorm electrojet developed over College, it showed several fluctuations in magnitude as measured by the total field variations shown in the top trace in Figure 8. Each increase in current density was accompanied by an increase in the amplitude of the VLF return. There is one major, unexplained excursion in the VLF amplitude just after 1200 UT which does not correspond to any obvious feature in the College magnetometer data and which will be the subject of further study. One should keep in mind the very different "fields of view" of the heater and the magnetometer chain. The magnetic record is a record which integrates currents flowing over a wide region while the heater beam scans a volume of less than 100 km in width.

Because of the solenoidal nature of the field-aligned currents, ground magnetometers tend to be indicators of the ionospheric current fluctuations. Using a simple line model of the overhead current one can see that the fluctuations present ranged to about 5 or $6x10^4$ amperes. This corresponds to an approximate current density of 1 microamp per square meter. However, it has been shown by satellite studies (for example, Iijima and Potemra, 1978) that the field-aligned currents which lie on the northern and southern borders of the westward electrojet can differ by a factor of two or more. Thus, some of the variations observed in the College magnetometer record are surely due to field-aligned currents. Since the field-aligned currents tend to flow along sheets oriented east-west, the net magnetic fields they produce should be observable primarily in the ground D component.

Clearly, this is a complicated and at the same time a very interesting and provocative set of observations. This data set is not complete enough to allow a complete description of the succession of ionospheric events which occurred on the night of June 12. For that we would need more ionospheric diagnostics to tell us the nature of the electric fields and/or conductivities. However, it does show that VLF modulation of the HIPAS beam can be used to track the amplitudes of the ionospheric currents. Dr. Ferraro has also obtained preliminary evidence that VLF polarization measurements can be useful in describing the direction of the radiating current element.

Finally, although the analysis of the June 12 data is still in an early form, we anticipate obtaining information on fine scale current variations when the data are examined in more detail. For example, we would expect the the primary ULF pulsation, the so-called Pi-2, pulsation which accompanies the substorm onset world-wide should be visible in both the magnetometer trace and the amplitude of the VLF return since the pulsation carries an electric field which should drive currents observable using the VLF modulated HIPAS beam. Observations of other long-period pulsations using VLF modulation of a radar beam, in the same frequency range have been reported by Reitveld, et al. 1987.

In sum, we believe that the use of the HIPAS beam modulated at VLF frequencies is a promising tool for the diagnosis of ionospheric currents, and that when combined with magnetometers and other instruments may allow fine scale observations which have not been hitherto available. We propose to explore this technique in more detail during the 1988-1989 campaigns as described below.

B. The search for ULF emissions

During several intervals of the June 1987 HIPAS campaigns, the beam was modulated at ULF frequencies between 0.01 Hz and 8 Hz. We operated the Geophysical Institute induction coil magnetometer during these periods and analyzed the data collected. At no time did we see ULF radiation above background corresponding to the HIPAS modulation frequency. It should be noted that we did not attempt to ULF modulation during times of strong electrojet activity.

During the period from 1800-2400 local time on June 15, a campaign was undertaken using ULF modulation of the HIPAS beam operating in the x-mode. A series of frequencies were used including 8, 6, 4, 2, 1, 0.1 and 0.01 Hz in a half hour cycle during which each the modulation was held constant for five minutes at one frequency before moving to the next. As ambient ULF fluctuations were present, there was some variation in the actual sequence of frequencies. Figure 9 shows a typical power spectrum taken from the induction magnetometer. One can see that the spectrum is monotonic and generally featureless. In fact, it represents the ambient background often observed during quiet intervals. Table 3 lists the threshold signal amplitudes corresponding to the spectral levels in Figure 9.

Table 3

Frequency hertz	B rms picoTesla
8.0	0.99
6.0	0.92
4.0	1.27
2.0	1.70
1.0	3.40
0.1	86.0
0.01	1360

Although the opportunity may arise to test new ideas for ULF modulations of the ionosphere, we do not plan to propose any further experiments ourselves. If other investigators do carry out ULF experiments we will be happy to provide real time data collection and analysis using the induction magnetometer at the Geophysical Institute.

V. References

Akasofu, S.-I., B.-H. Ahn and G. J. Romick, A study of the polar current systems using the IMS meridian chains of magnetometers, *Space Science Reviews*, **36**, 337, 1983.

Hughes, T. J. and G. Rostoker, Current Flow in the magnetosphere and ionosphere during periods of moderate activity, *J. Geophys. Res.*, **82**, 2271, 1977.

Hughes, T. J. and G. Rostoker, A comprehensive model current system for high-latitude magnetic activity–I. The steady state system, *Geophys. J. R. astr. Soc.*, **58**, 525, 1979.

Hughes, T. J., D. W. Oldenburg and G. Rostoker, Interpretation of auroral oval equivalent current flow near dusk using inversion techniques, *J. Geophys. Res.*, **84**, 450, 1979.

Iijima, T. and T. A. Potemra, Large-scale characteristics of field-aligned currents associated with substorms, *J. Geophys. Res.*, **83**, 599, 1978.

Rietveld, M. T., H.-P. Mauelshagen, P. Stubbe, H. Kopka, and E. Nielsen, The characteristics of ionospheric heating-produced ELF/VLF waves, *J. Geophys. Res.*, **92**, 8707, 1987.

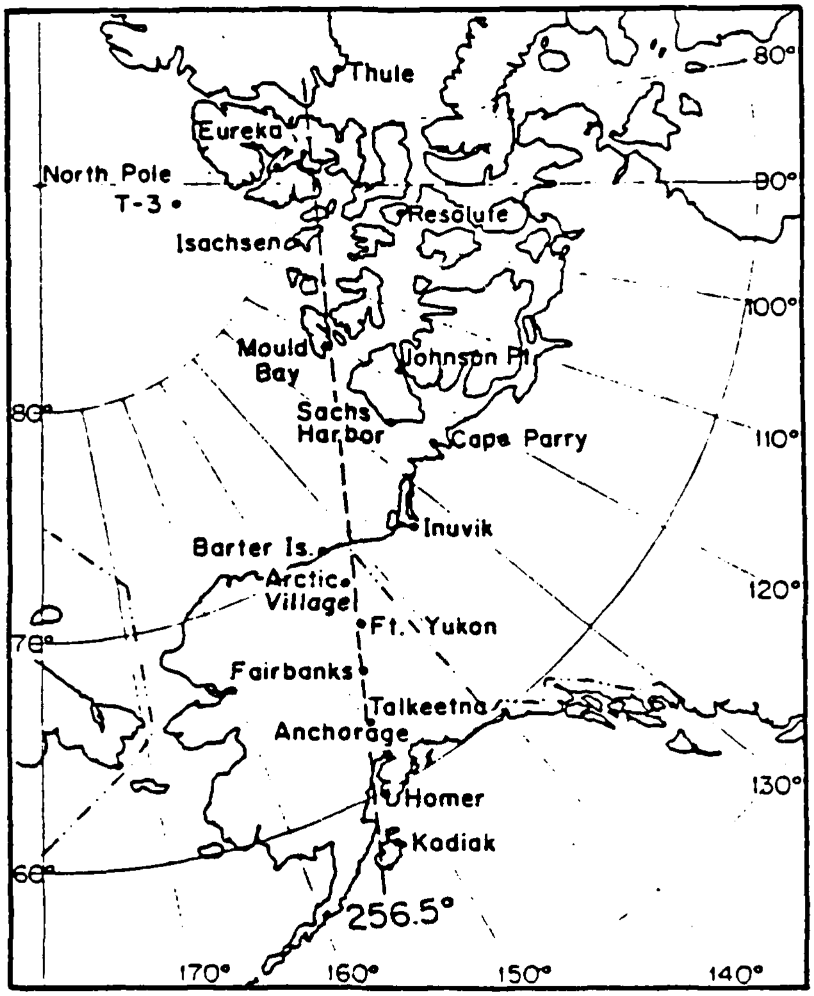

Figure 1
The location of the Alaska meridian chain of magnetometers.

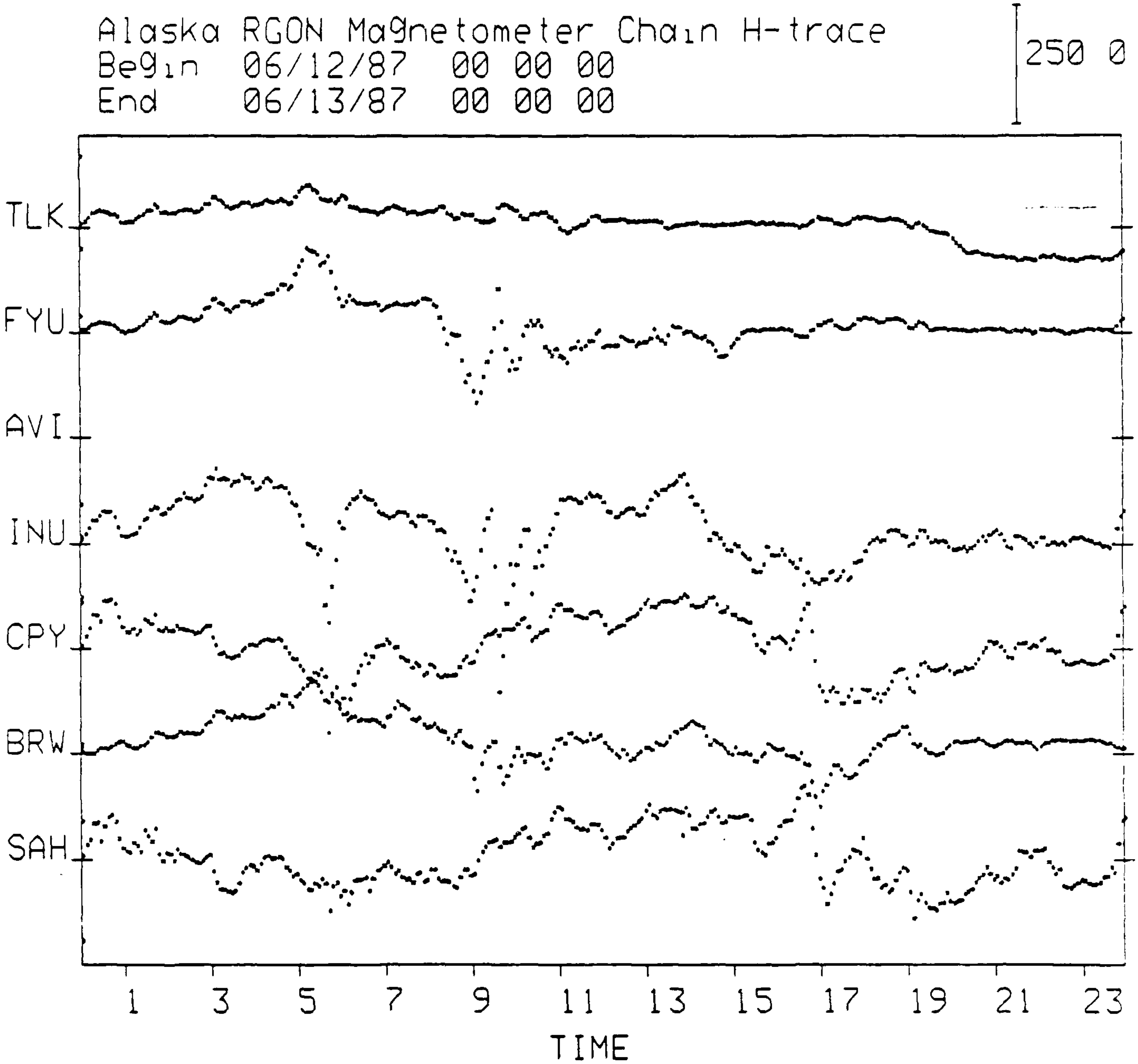

Figure 2
H component magnetometer records from stations along the Alaska meridian chain of magnetometers for June 12, 1987.

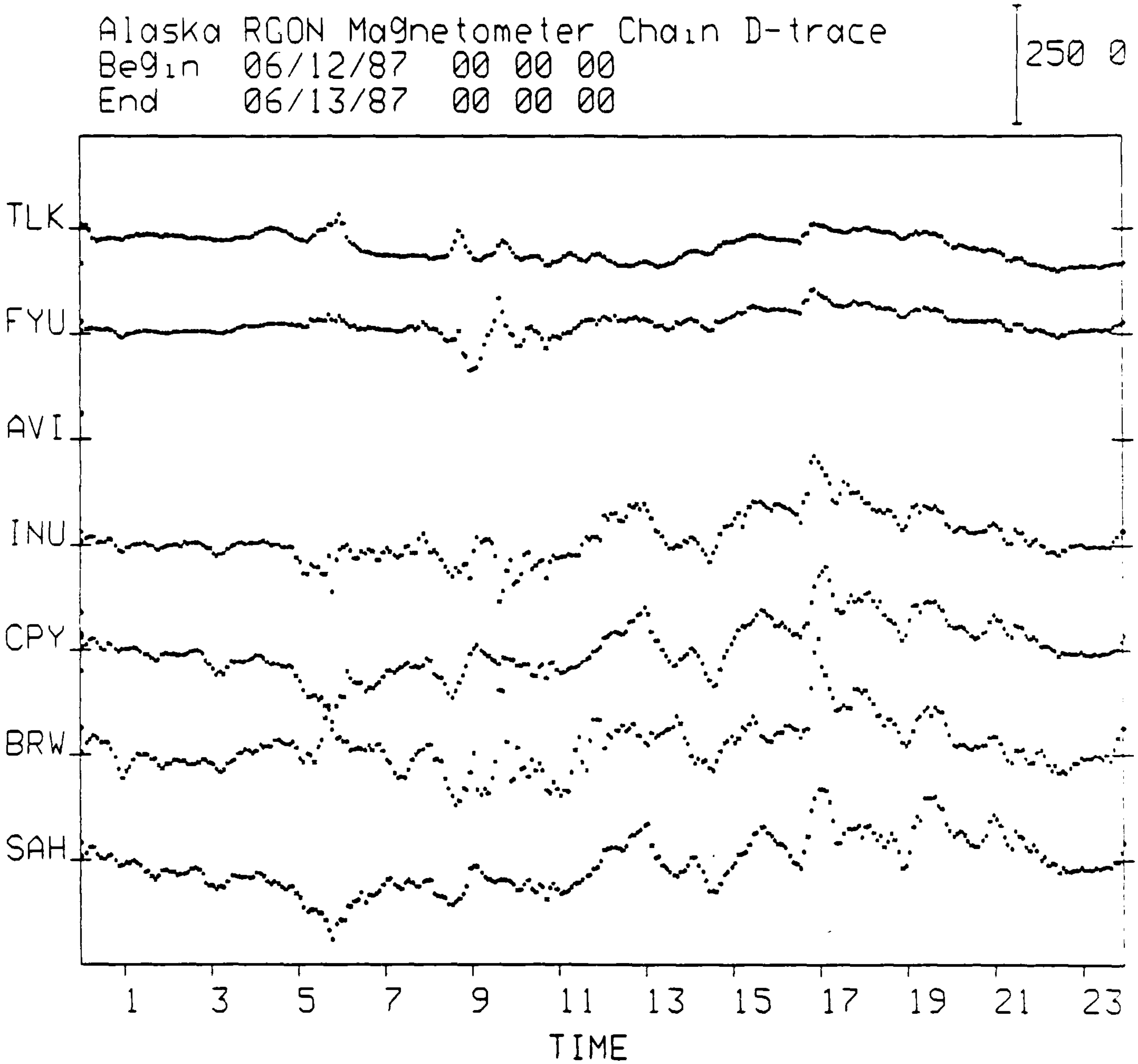

Figure 3
D component magnetometer records from stations along the Alaska meridian chain of magnetometers for June 12, 1987.

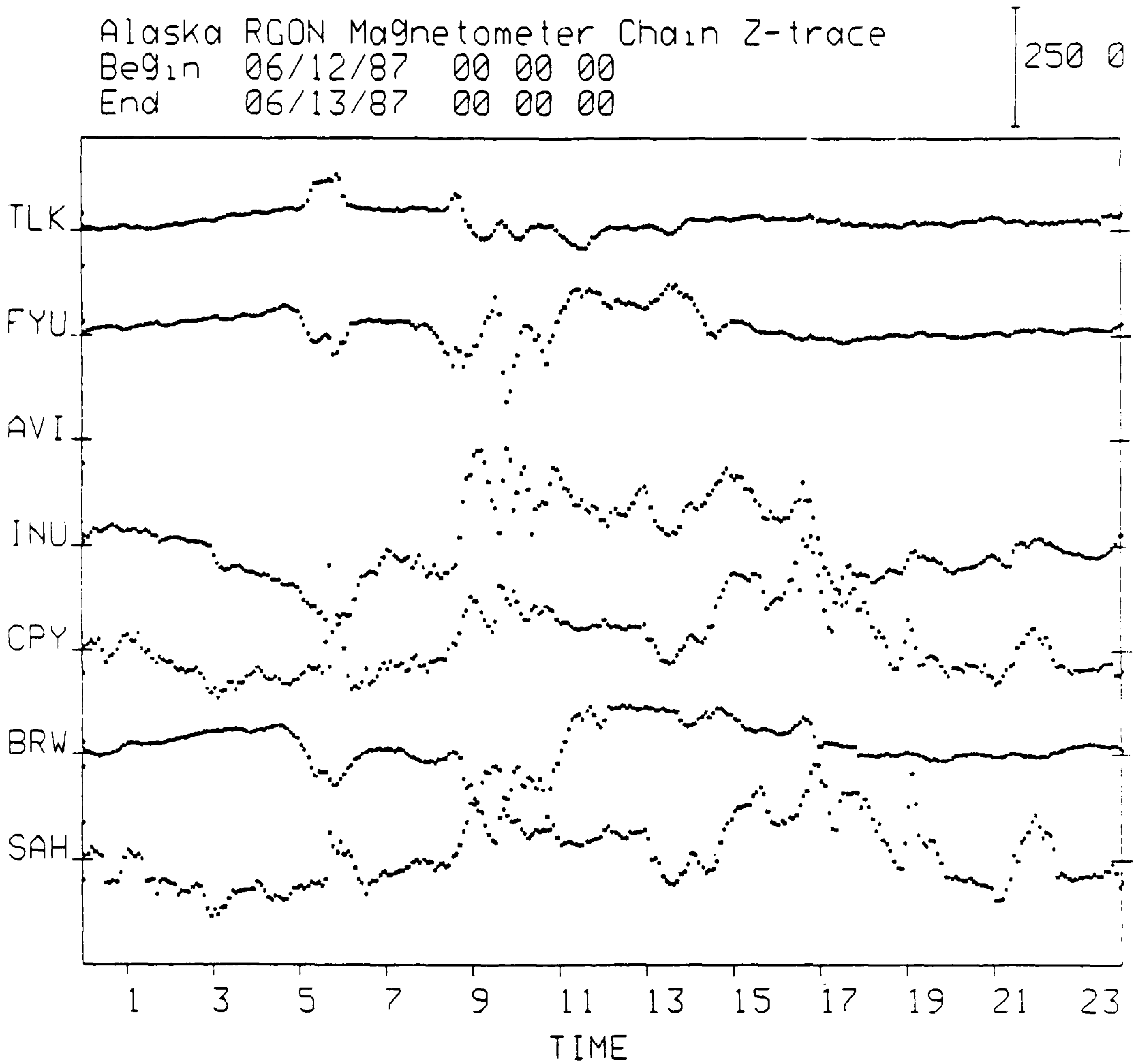

Figure 4

Z component magnetometer records from stations along the Alaska meridian chain of magnetometers for June 12, 1987.

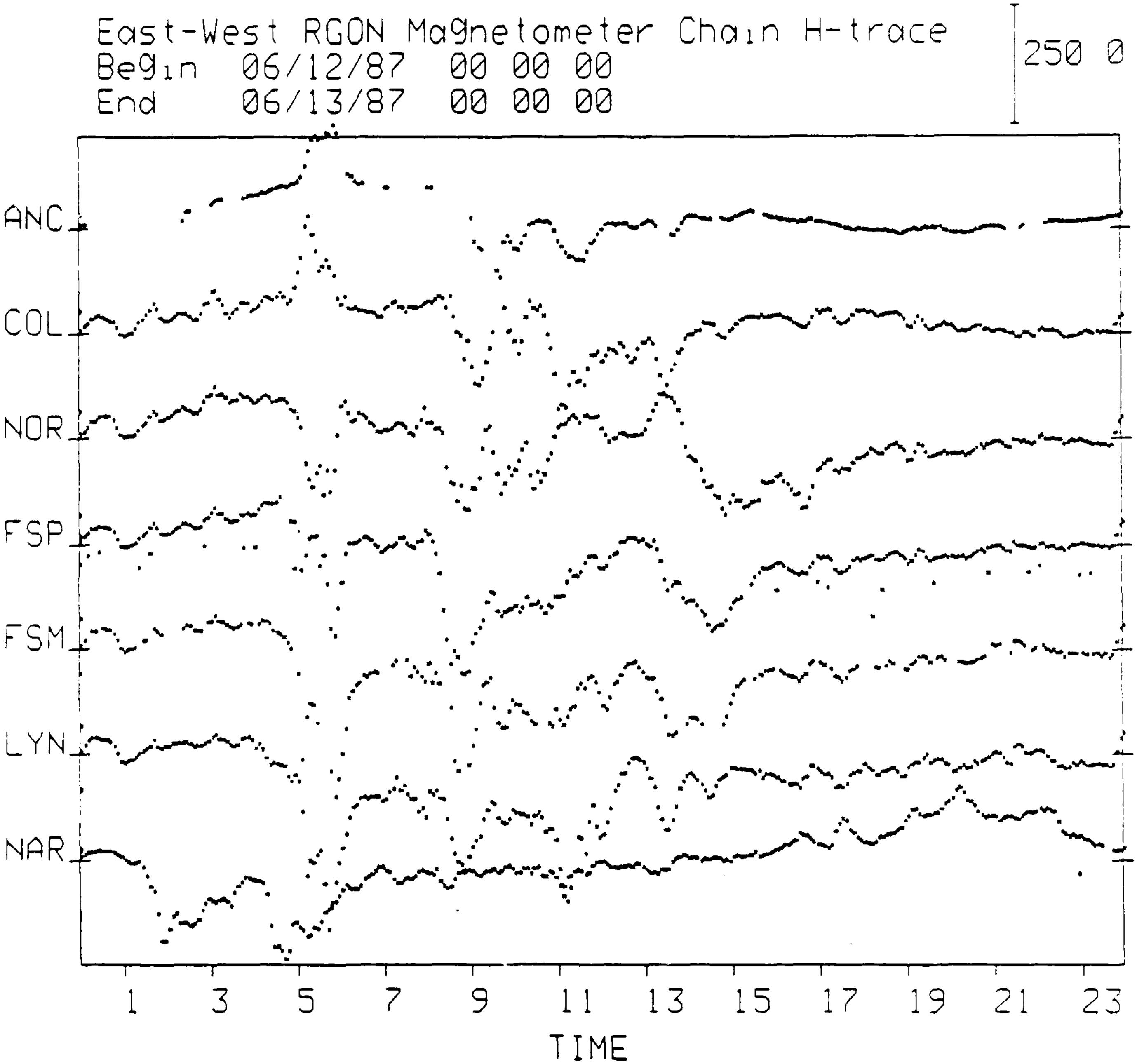

Figure 5
H component magnetometer records from stations along the East-west chain of magnetometers for June 12, 1987. Note that College (COL), which lies in the Alaska meridian chain, is included here.

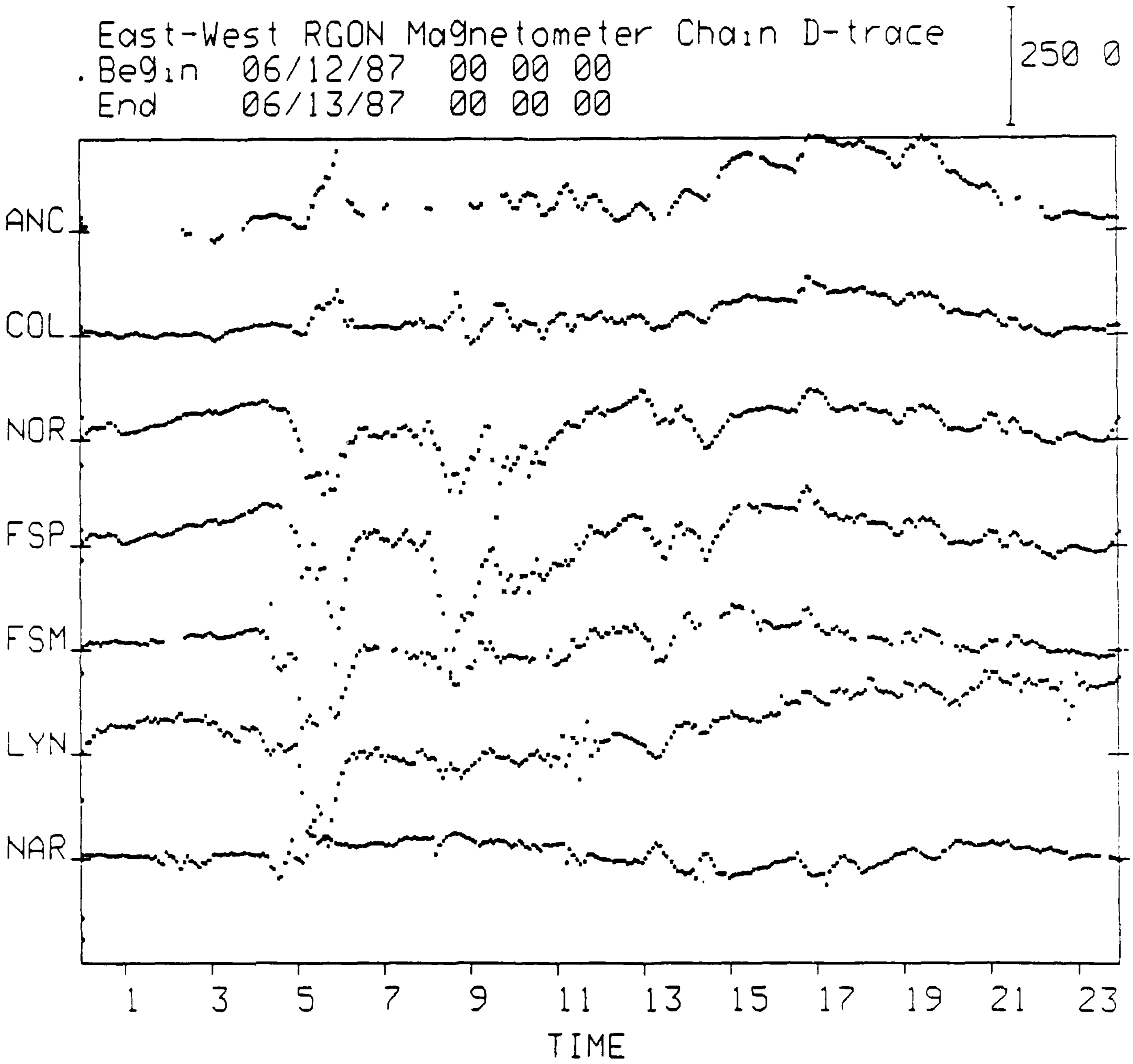

Figure 6
D component magnetometer records from stations along the East-west chain of magnetometers for June 12, 1987. Note that College (COL), which lies in the Alaska meridian chain, is included here.

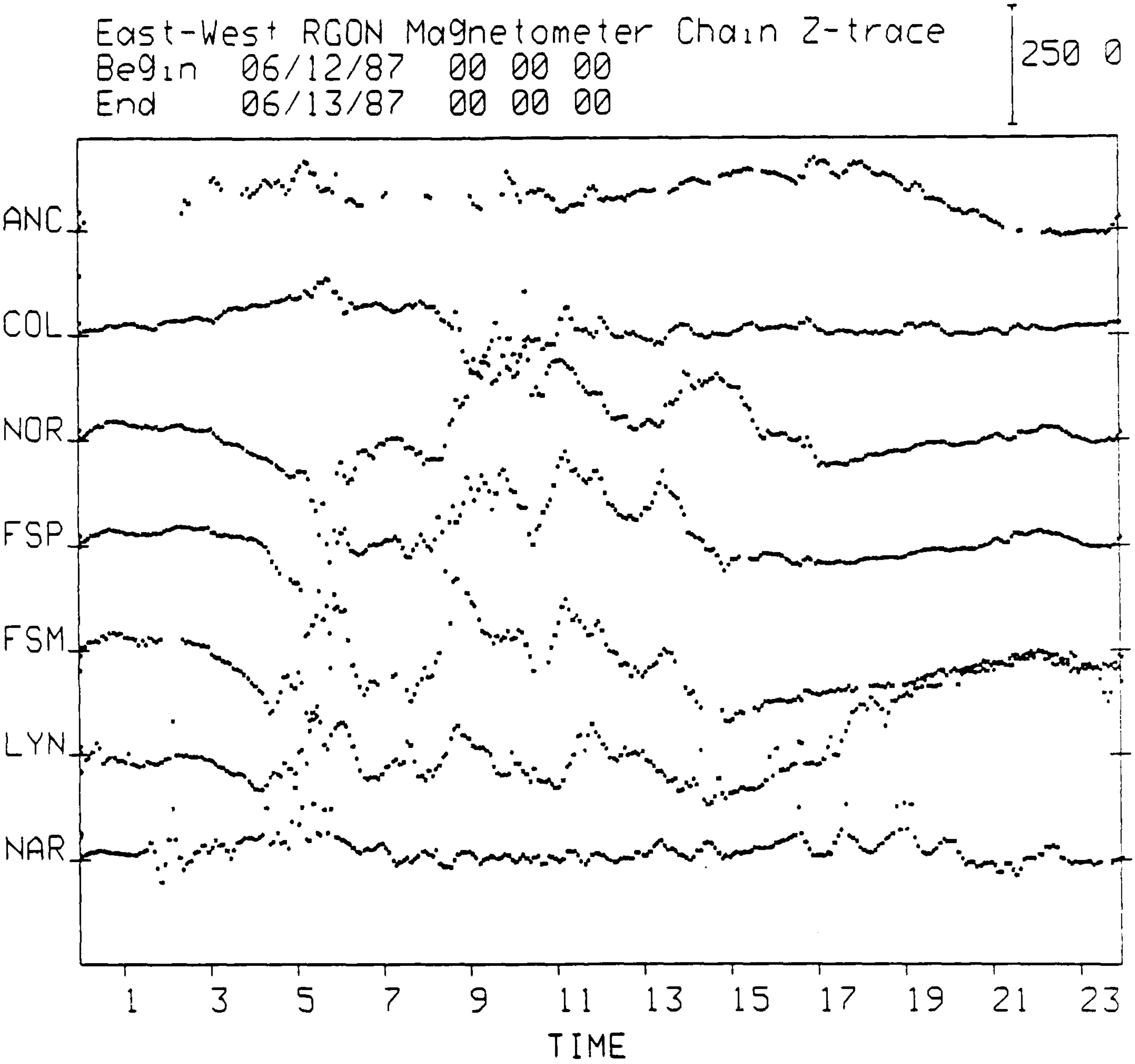

Figure 7
Z component magnetometer records from stations along the East-west chain of magnetometers for June 12, 1987. Note that College (COL), which lies in the Alaska meridian chain, is included here.

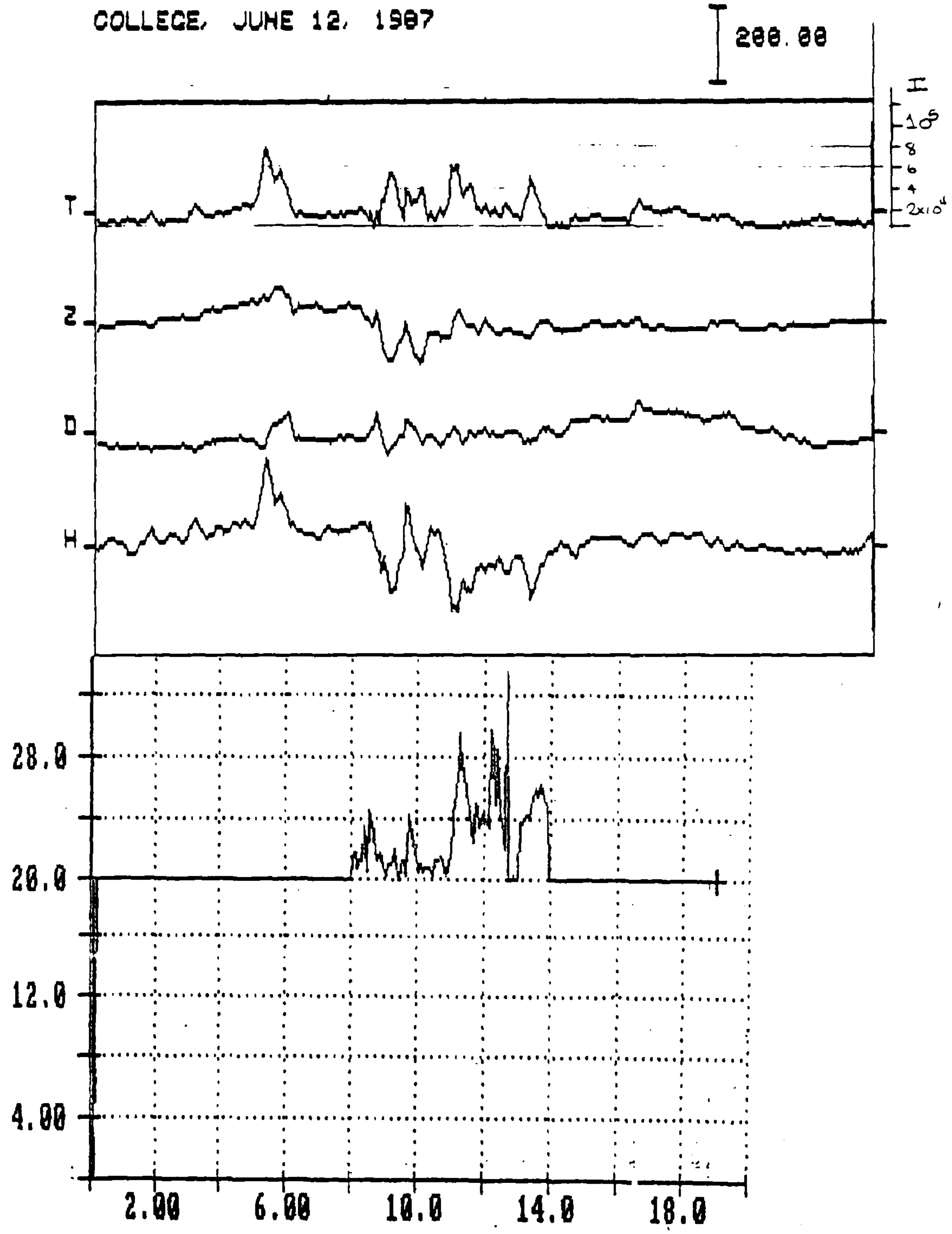

Figure 8
VLF signal amplitudes observed during the June 12, 1987 campaign together with the magnetometer records from the College magnetometer. The top trace is the magnitude of the magnetometer variations for this interval. Note the strong correlations between the VLF amplitudes and the D component traces between 0800 and 1000 UT when the westward travelling surge was overhead.

JUNE 25, 1987 H BACKGROUND
AVERAGE OF 4.0000 SPECTRA

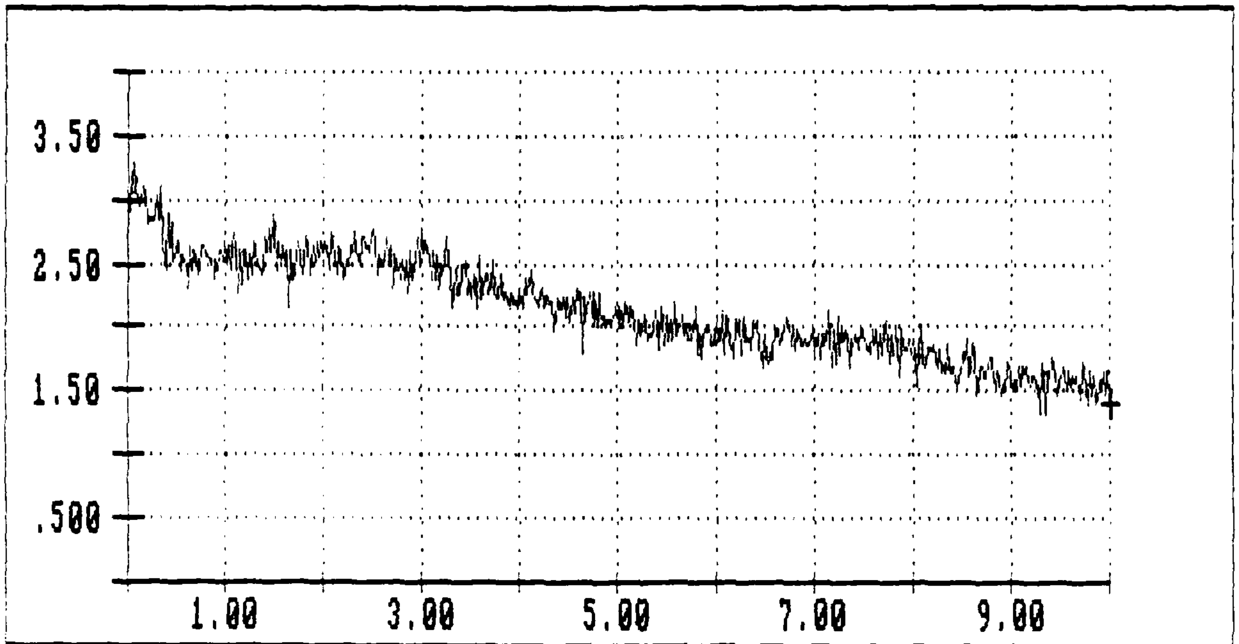

Figure 9
The ULF spectrum measured with the Geophysical Institute induction magnetometer during the June 25, 1987 ULF campaign. This spectrum shows the ambient background present during the campaign.